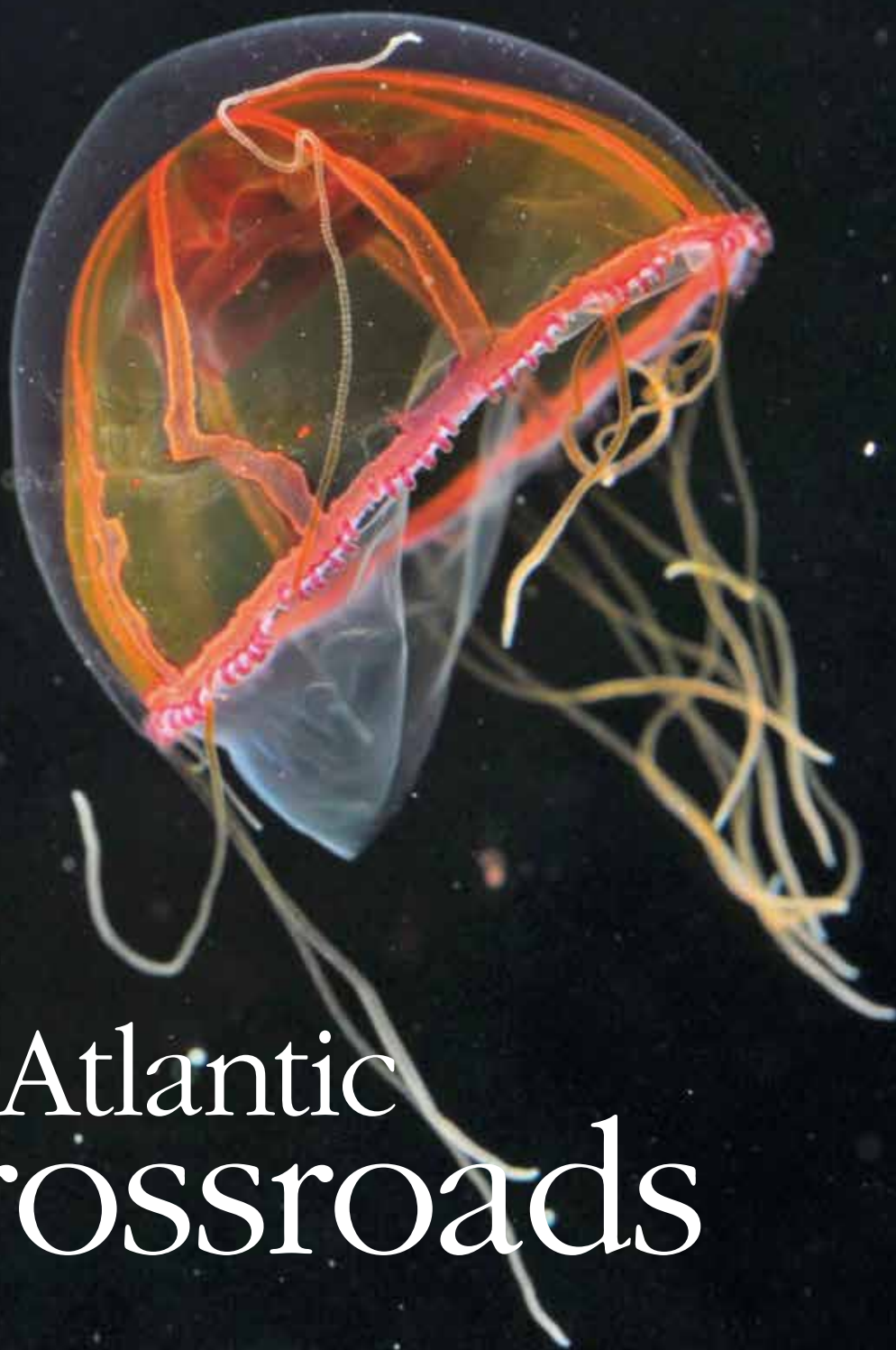


Planet Earth

NERC SCIENCE OF THE ENVIRONMENT

www.planeteearth.nerc.ac.uk

Spring 2014



Mid-Atlantic crossroads

Seismology in North Korea • Gravel maps • Amazon peatlands • Cambodian floods

About us

NERC – the Natural Environment Research Council – is the UK's leading funder of environmental science. We invest public money in cutting-edge research, science infrastructure, postgraduate training and innovation.

Our scientists study the physical, chemical and biological processes on which our planet and life itself depends – from pole to pole, from the deep Earth and oceans to the atmosphere and space. We work in partnership with other UK and international researchers, policy-makers and business to tackle the big environmental challenges we face – how to use our limited resources sustainably, how to build resilience to environmental hazards and how to manage environmental change.

NERC is a non-departmental public body. Much of our funding comes from the Department for Business, Innovation and Skills but we work independently of government. Our projects range from curiosity-driven research to long-term, multi-million-pound strategic programmes, coordinated by universities and our own research centres:

British Antarctic Survey
British Geological Survey
Centre for Ecology & Hydrology
National Oceanography Centre
National Centre for Atmospheric Science
National Centre for Earth Observation

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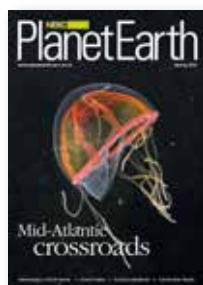
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Planet Earth is NERC's quarterly magazine, aimed at anyone interested in environmental science. It covers all aspects of NERC-funded work and most of the features are written by the researchers themselves.

For the latest environmental science news, features, blogs and the fortnightly *Planet Earth* Podcast, visit our website *Planet Earth* Online at www.planeteearth.nerc.ac.uk.

Not all of the work described in *Planet Earth* has been peer-reviewed. The views expressed are those of individual authors and not necessarily shared by NERC. We welcome readers' feedback on any aspect of the magazine or website and are happy to hear from NERC-funded scientists who want to write for *Planet Earth*. Please bear in mind that we rarely accept unsolicited articles, so contact the editors first to discuss your ideas.

Front cover: Deep-sea jellyfish. *David Shale*



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News

Editorial

Welcome to the Spring issue of *Planet Earth*. This time we have a decidedly international flavour, with stories on exciting NERC-funded research in far-flung parts of the globe.

Probably the most unusual destination was North Korea. Very few people get to visit the world's most isolated nation, and for those who do most of the country is off-limits.

But science doesn't stop at national frontiers, and we report on the remarkable trip James Hammond and Clive Oppenheimer made to work with North Korean scientists on a remote volcano that many fear may be stirring after a millennium of slumber.

Meanwhile Tom Kelly and Freddie Draper describe how they are unlocking the secrets of the vast and little-explored peatlands of the Amazon, and Chris Hackney writes about his team's expedition

to Cambodia. When they headed off

to study flooding on the Mekong River they expected a fair bit of water – but they didn't anticipate that a combination of monsoon and typhoon would create one of the river's biggest-ever floods.

Other stories highlight the value of long-term monitoring. These initiatives may not hit the front pages often, but they're essential for understanding the subtle but profound changes that are taking place in our environment. Find out more in our articles about a global scheme to monitor the state of the atmosphere, and about a major effort to track the health of our lakes.

For more pictorial evidence of the amazing variety of NERC-funded science, turn to page 16 to see the winners in NERC's first-ever PhD student photography competition, and see the back cover for a few of our other favourites. From seal skulls to weighing elephants and a seriously gruesome picture of burying beetles going about their business – all in a day's work!



Extreme El Niños set to double as climate warms

Extrême El Niño events, which disrupt rainfall around the world, are predicted to double over the next century.

Until recently it was thought that the weather phenomenon, characterised by warming in the eastern and tropical Pacific Ocean, would be relatively unaffected by climate change. But a new study, published in *Nature Climate Change*, says we're now likely to see an extreme El Niño every decade. It follows research published last year which forecast a rise in El Niño intensity.

'This is a highly unexpected consequence of global warming,' says Professor Mat Collins of the University of Exeter, one of the authors. 'Tropical rainfall conditions such as those experienced in extreme El Niños can have a dramatic influence on the world, through flooding rains, bushfires and drought. The impact on people, in particular fishermen in developing nations or farmers, is substantial.'

'It is essentially an irreversible climate-change phenomenon,' Collins adds. 'It would take a dramatic reduction in greenhouse emissions over a number of generations to reduce its impact.'

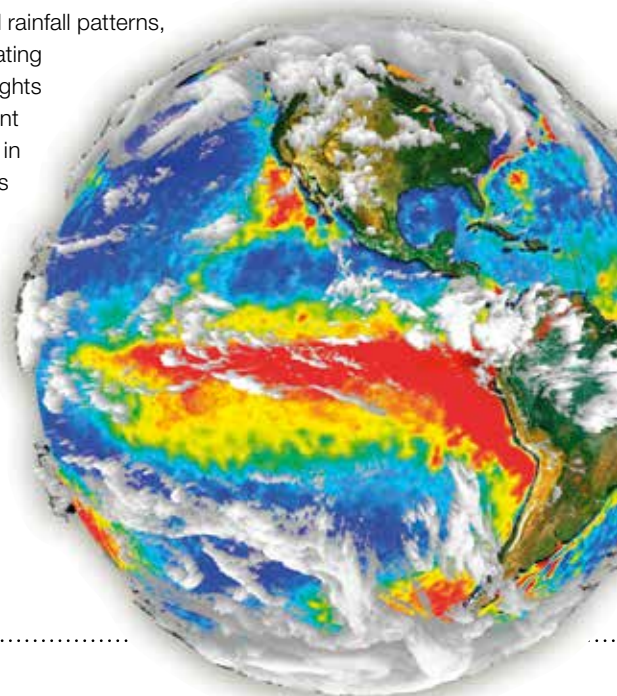
El Niño is part of a cycle of warming and cooling from one side of the Pacific Ocean to the other. It's driven by the complex relationship between the region's winds, sea-surface temperatures and ocean currents. Its sister phenomenon, La Niña, sees a cooling of temperatures in the eastern Pacific, but increased heat and moisture in the west. Together, they're known as the El Niño Southern Oscillation (ENSO).

Poring over 20 separate simulations of future climate, the international team consistently found pronounced warming in the eastern Pacific over the next century. Those perpetually warmer waters will mean a relatively modest hike in temperatures from El Niño could affect global rainfall dramatically.

The last extreme event in 1997-98

disrupted global rainfall patterns, bringing devastating floods and droughts to every continent and an upsurge in tropical cyclones in the Pacific.

It claimed an estimated 23,000 lives and caused \$35-45 billion in damage.





The Swarm satellite mission, which will measure the Earth's magnetic field in more detail than ever before, launched in November 2013.

The trio of satellites, each the size of a small car, took off from the Plesetsk Cosmodrome in Russia. As well as providing immediate improvements to navigation maps used in smartphones, the European Space Agency mission will monitor interactions between the Earth's magnetic field and the Sun's atmosphere.

This could help us prepare for adverse space weather, which threatens to disturb vital communication and navigation systems. 'This exciting mission will help us solve some long-standing puzzles about the Earth's magnetic field, and hopefully discover a few new ones along the way,' says Dr Ciaran Beggan, of NERC's British Geological Survey (BGS).

Most of Earth's magnetic field, sometimes referred to as its magnetosphere, originates from deep within its interior, stretching all the way out into space where it meets the solar wind – the constant stream of tiny charged particles released into space from the outer layers of the Sun. But processes in the rocks beneath our feet, the atmosphere and the oceans also produce magnetism.

Two of the three identical Swarm satellites will orbit the Earth at a height of 450 kilometres, mapping the more subtle features of the Earth's magnetic field with more precision than ever before. The third will operate higher up at around 530 kilometres, monitoring the interactions between the magnetosphere and the atmosphere of our parent star.

Working alongside European colleagues, BGS will process the magnetic data the satellites collect. All of the data will be made freely available from the ESA website.

Studies highlight differences between banned pesticides



Two separate studies add new weight to the idea that some varieties of controversial neonicotinoid pesticides are less harmful to bees than others.

The research tested the effects of feeding two different neonicotinoids, thiamethoxam and imidacloprid, to bumblebees. The EU recently banned both over concerns about their effects on bee health.

Ian Laycock from the University of Exeter led the studies, published in *PLoS ONE* and *Ecotoxicology and Environmental Safety*. 'We found that both thiamethoxam and imidacloprid were capable of repressing feeding and brood production in bumblebees,' he says. 'But with thiamethoxam this only happened with very large concentrations of the pesticide – concentrations that bees are unlikely to encounter in the environment.'

In contrast, imidacloprid halved both egg production and pollen consumption even at the very low concentrations that bees are likely to encounter when they forage on treated crops.

'We think this is because imidacloprid produces a stronger repression of feeding in bumblebees than thiamethoxam, and this imposes a greater limitation on the bees' ability to produce eggs,' says Laycock.

The research also had some better news for bees. After two weeks' exposure, the bees were allowed to recuperate, and seemed to bounce back well. This kind of 'pulsed' exposure is designed to replicate the scenario in the wild, where bees feed on mass-flowering crops, like oil-seed rape, for just a few weeks while they're in flower, before switching back to pesticide-free wildflowers.

In December last year, the EU introduced a two-year moratorium on neonicotinoids. The UK voted against the ban, citing a lack of evidence of harm to bees in field studies. Laycock says the evidence against imidacloprid is probably strong enough to justify a temporary ban, giving researchers time to study its effects. But we shouldn't tar all neonicotinoids with the same brush. 'Our study shows we cannot simply apply the conclusions about the safety of imidacloprid to other neonicotinoids,' he says.

News



Japan tsunami exacerbated by landslide

The 2011 Japan tsunami, which killed up to 20,000 people and caused the partial meltdown of the Fukushima nuclear plant, was made worse by an underwater landslide, according to scientists.

Until now, the lethal waves were blamed solely on the magnitude-nine earthquake which struck at sea to Japan's east. But an international team led by Professor Dave Tappin of NERC's British Geological Survey says the earthquake alone wouldn't have been enough.

'The earthquake alone cannot explain the height of the waves along the Sanriku coast of northern Honshu Island,' he says.

'They were generated by a submarine landslide.' He says this raises a big problem for early-warning systems. If the risk of landslides isn't recognised, tsunami risk could be badly underestimated.

It's well known that landslides can generate tsunamis on their own, and research on the Papua New Guinea event of 1998 showed that landslides triggered by small earthquakes could also produce devastating waves. But this is the first research to recognise the significant contribution that underwater landslides can make to tsunamis generated by giant quakes.

'With the Japan tsunami, for the first time we had offshore wave data recorded at GPS buoys,' says Tappin. 'This allowed us to identify the most likely location of the landslide.'

'Using maps of the seabed, we identified a landslide that was 40 kilometres wide, 20 kilometres long and 2 kilometres thick. That makes it 500 cubic kilometres, so it's pretty big.'

'We then used computer models to simulate the tsunami from a dual source: the earthquake and the landslide, and this gave us the high water levels along the north Honshu coast.'

Fungi crucial for biodiversity in rainforests

Fungi play a vital role in maintaining the diversity of life in tropical forests, say scientists.

Where plants are densely packed together, seedlings are less likely to survive if they germinate near others of the same species.

A new study in *Nature* says this may be because fungi spread quickly between plants of the same species – helping promote diversity by preventing competitive species from dominating, and allowing rarer species to flourish.

'Diversity provides an insurance policy,' explains Dr Owen Lewis of Oxford University, senior author on the study. 'If you have low diversity the ecosystem would be very vulnerable to changes in environment, like climate change. A wide range of plants means the system won't collapse if something changes.'

Fungi do well in warm, damp conditions, so climate change could have a huge impact on rainforest biodiversity.

'Interestingly the places with highest plant diversity are also the hottest and most humid. Fungi probably operate most

strongly in those very hot and wet places. If humans start altering the climate that could alter these important interactions between species,' Lewis continues. 'Plants are the building blocks of a whole ecosystem too. If you have low plant diversity then you'll have low diversity in animals too since plants are at the bottom of the food chain.'

The team studied seedlings at 36 plots in Belize. They found a higher diversity of seedlings germinating, compared with the seeds that originally rained down from the canopy. They suspected something in the soil was responsible for the difference.

Spraying some of the plots with fungicides reversed the situation so that abundant plants no longer did better than would be expected and rare species no longer did worse, suggesting fungi were responsible.



R.Bagchi



How did the cobra get its bite?

A new study has shed new light on how snake venom evolved into the sophisticated cocktail of different toxins it is today.

It turns out that snakes' venom glands have co-opted many proteins that originally played more mundane roles elsewhere in their bodies. Constant innovation helped them stay ahead of prey animals, which become resistant to particular venoms over time.

Researchers at Bangor University, the Liverpool School of Tropical Medicine and the universities of Leiden in Holland and Texas, Arlington in the USA sequenced genomes of the deadly king cobra and the non-venomous Burmese python, and compared the two to help understand how each evolved.

Cobra venom contains dozens of highly-specialised toxins, and exactly how this complex brew could have come about has long been a puzzle. Analysing the snake's genome confirmed that the toxins developed from proteins that originally evolved for more workaday tasks.

The genes responsible for these proteins have been duplicated many times, so the original version could keep doing its job while the copy mutated further and took on new functions. This let the proteins taken up by the venom system multiply and diversify away from their original purposes,

forming lethal suites of chemicals that interact with each other to do more harm to prey.

The results, which probably apply to other venomous snakes, will help scientists develop better antivenoms that protect against the bites of many snake species.

The paper appears in *Proceedings of the National Academy of Sciences*.



Glacier's retreat may be irreversible

Pine Island Glacier, the largest single contributor to sea-level rise in Antarctica, has started shrinking, say scientists.

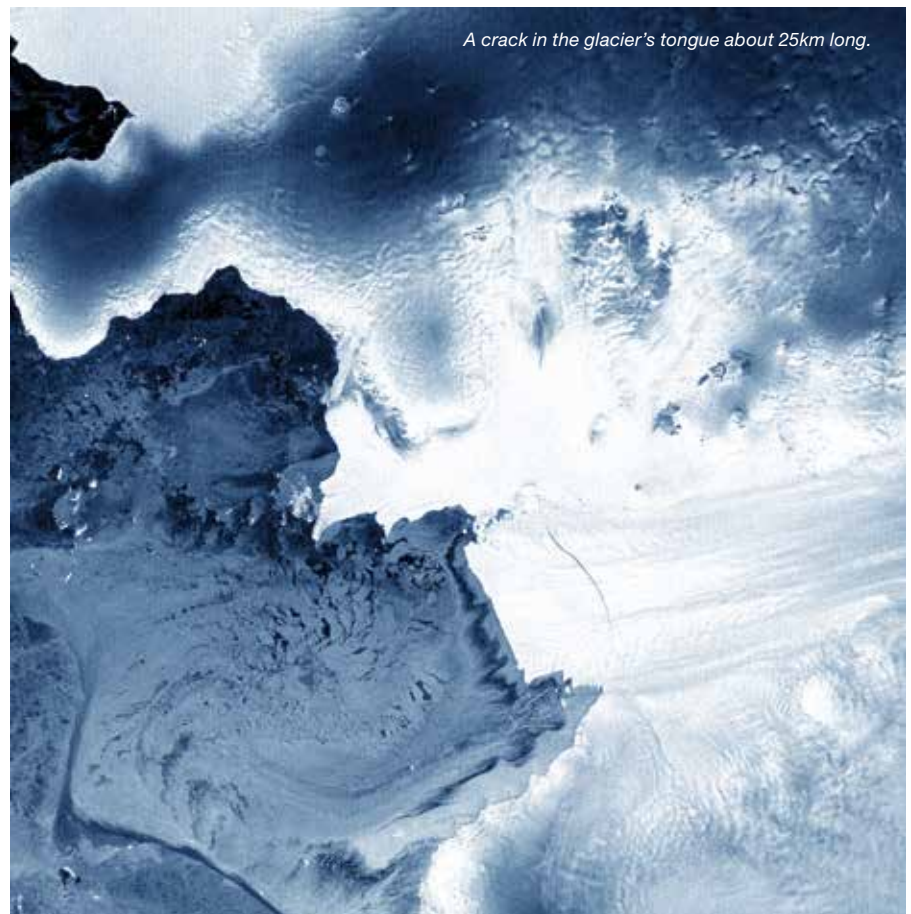
Their work, published in *Nature Climate Change*, shows the glacier's retreat may have begun an irreversible process that could see the amount of water it is adding to the ocean increase five-fold.

'At the Pine Island Glacier we have seen that not only is more ice flowing from the glacier into the ocean, but it's also flowing faster across the grounding line – the boundary between the grounded ice and the floating ice. We also can see this boundary is migrating further inland,' says Dr G Hilmar Gudmundsson from NERC's British Antarctic Survey, a researcher on the project.

The team used three computer models as well as field observations to study how the glacier's ice flows and to simulate how this will change. All the models agreed that the Pine Island Glacier has become unstable, and will keep retreating for tens of kilometres.

'The Pine Island Glacier shows the biggest changes in this area at the moment, but if it is unstable it may have implications for the entire West Antarctic Ice Sheet,' says Gudmundsson. 'Currently we see around two millimetres of sea-level rise a year, and the Pine Island Glacier retreat could contribute an additional 3.5-5 millimetres in the next 20 years, so it would lead to a considerable increase from this area alone. But the potential is much larger.'

The retreat of the Pine Island Glacier currently contributes 25 per cent of the total ice loss from West Antarctica. If the entire West Antarctic Ice Sheet was to retreat, it could cause sea level to rise up to five metres.



ESA

News



Radar reveals amazing ladybird flight paths

Ladybirds aren't widely known for their amazing feats on the wing, but scientists examining radar data have spotted the tiny creatures flying 1100 metres up and at speeds of up to 60 kilometres an hour.

The discovery, published in the journal *PLoS ONE*, means in theory ladybirds could make it from London to Birmingham in just over two hours. This could explain why invasive insects like the harlequin ladybird have managed to spread across Britain so quickly.

It also suggests that ladybirds can travel further in warmer temperatures, so climate change could exacerbate our problems with alien invaders.

Dr Lori Lawson Handley, from the University of Hull, led the research. 'These are the first recordings of ladybirds travelling at such extraordinarily high altitudes,' she says. 'Ladybirds are very capable flyers on their own, but this puts them up in the stronger winds where they can travel faster and farther.'

The team worked out what a ladybird would look like to a radar scanner through laboratory tests. They then pored back through radar data collected throughout the past ten years above the Rothamsted research centre in Hertfordshire, UK.

Most of the ladybirds were found at heights between 150 and 500 metres above the ground, flying at an average speed of 30 kilometres an hour. But some were found at even higher altitudes, travelling even faster.

In separate experiments, the team recorded the flight times of ladybirds in a Perspex box. The average flight lasted 36.5 minutes, with some going on for as long as two hours.

Grey squirrels stop garden birds using feeders

The presence of grey squirrels cuts the number of birds visiting hanging bird feeders by 98 per cent, new research reveals.

So, if you're one of the third of households that provides food for birds during the winter, scientists suggest opting for squirrel-proof feeders rather than standard models.

'We've clearly demonstrated that grey squirrels will affect garden birds' use of a feeder,' says Dr Karl Evans of the University of Sheffield, who oversaw the

study, published in *Ibis*.

'Whether or not these findings have a long-term impact on common garden birds will depend on how quickly they can find an alternative food source. The effect will be most keenly felt by birds in areas that support lots of grey squirrels and that don't have many feeders,' he adds.

Evans and colleagues presented garden birds in Sheffield with three different bird feeders. One was a normal feeder filled with sunflower seeds. Another was the same, but included a piece of grey card

the same size as a squirrel stuck to it – the control. Finally, the test feeder included a normal bird feeder with a stuffed grey squirrel attached to it – the squirrel feeder.

In almost all cases, the most common garden birds stopped using the squirrel feeder, but carried on using the others. The only bird not deterred by the squirrel was the European Robin.

The researchers also watched garden birds using a feeder with real grey squirrels present; the results were similar.



Top conservation threats and opportunities for 2014

Governments being forced to choose between addressing climate change or averting a financial crisis; super-cheap solar cells; accelerated loss of rhinos and elephants – these are all among 15 conservation issues scientists say may become significant this year.

Others include emerging snake fungal disease and using synthetic biology to resurrect extinct species.

The researchers say current stock-market valuations of the fossil-fuel industry are incompatible with government commitments to prevent global average temperature from rising more than 2°C.

Estimates suggest coal, oil and gas reserves in the ground are worth

some \$4 trillion. But their value could drop dramatically if they aren't burned because emissions regulations come into force, potentially leading to a financial crisis.

More positively, the researchers say carbon solar cells could overtake silicon-based ones as a source of renewable energy. Mass production could lead to cheap cells that could be installed on land, in water or even be worn.

The topics are the result of an attempt to pinpoint conservation threats, opportunities and developments that scientists haven't given much attention, so that appropriate research could reduce the risk they'll turn into big problems in the future.

THE FULL LIST OF EMERGING ISSUES

Response of financial markets to unburnable carbon

Extensive land loss in south-east Asia from subsidence of peatlands

Carbon solar cells as alternative source of renewable energy

Rapid geographic expansion of algae cultivation for biofuels

Redistribution of global temperature increases among ecosystems

High-frequency monitoring of land-cover change

Reaccelerated loss of wild rhinoceroses and elephants

Increasing scale of eradications of non-native mammals on islands

Self-sustaining genetic systems for control of non-native invasive species

Probiotic therapy for amphibians

Emerging snake fungal disease

Polyisobutylene as a marine toxicant

Exploitation of Antarctica

Expansion of ecosystem red listing

Resurrection of extinct species using synthetic biology

in brief . . .

► New oil and gas training centre announced

NERC is investing £2.8 million in a new Centre for Doctoral Training (CDT) that will help the energy industry put environmental science at the heart of responsible management of our planet. Set up in collaboration with a consortium of universities and research organisations led by Heriot-Watt, the centre will support up to 60 students, focusing on creating a highly-skilled workforce with expertise that can be used across the wider energy and environment sectors as well as filling skills gaps in oil and gas. The consortium has already committed to invest a further £5.2 million, and more financial support is expected from business and overseas universities.

► UK environmental science leads the world

The latest biennial report on the International Comparative Performance of the UK Research Base has been released. Commissioned by the Department for Business, Innovation & Skills, it ranks UK environmental science first in the world by citation impact – a measure of excellence based on how much research is cited by other researchers writing in high-quality publications. It also found that it leads all other UK research fields by the same measure, and that UK research in general punches well above its weight, with the highest productivity in the world per unit spent on research.

► Gateway to Research

Research Councils UK (RCUK) has launched Gateway to Research, a web portal that provides detailed information on more than 42,000 research projects supported across all the UK's seven research councils and the Technology Strategy Board. The site gives businesses and other users of research direct access to new developments that could lead to new commercial opportunities. It also helps them identify potential partners in universities, so that research can be used more widely and create greater social and economic benefit. All the information on GtR is freely available to all via <http://gtr.rcuk.ac.uk>.

News

Sun's role in climate change 'minimal'

The Sun's influence on the Earth's climate over the past millennium has been minimal, and this probably won't change in the coming centuries.

A paper in *Nature Geoscience* says volcanic eruptions and greenhouse gases were the main factors behind the substantial shifts in Earth's climate since 1,000AD.

Dr Andrew Schurer, of the University of Edinburgh, led the study. 'People have been suggesting that we're about to go into a solar minimum, where the Sun weakens and cools the climate,' he says.

'But our analysis shows that, over the past 1000 years, variations in the Sun's output have actually had very little influence over northern hemisphere temperatures, and we would expect that to continue into the near future.'

At the turn of the last millennium, the world was in the middle of what's become known as the medieval warm period – a 300-year spell of relatively warm climate. This was followed by a sharp drop in temperatures, known as the little ice age, lasting until around 1850.

'The Sun has been implicated in both periods, but the timings don't add up,' says Schurer.

'Our data show the clear influence of volcanic eruptions. When volcanoes erupt, they eject aerosols into the atmosphere, which block out the Sun, giving a cooling influence.'

'For the medieval warm period, we're seeing a lack of volcanic activity, which allows the climate to heat up. But when volcanic



ESA/SWAP PROBA2 science centre

activity kicks up again at the start of the little ice age, temperatures come back down.'

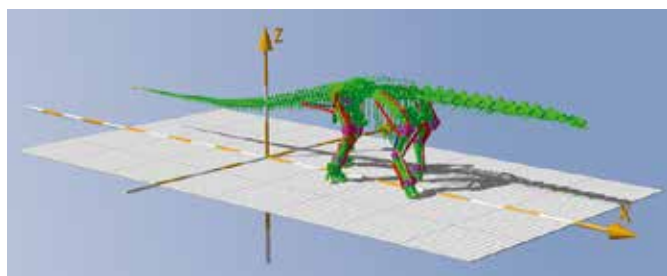
The team used existing records of past temperatures from a number of different sources, including tree rings, coral reefs and historical records, to build a picture of the Earth's climate over the past 1000 years.

Teaching Argentinosaurus to walk

Scientists have worked out how the biggest four-legged dinosaurs got from A to B.

New research in *PLOS ONE* set out to understand the gait of *Argentinosaurus* – one of the largest animals ever to walk the Earth.

Argentinosaurus is thought to have stretched 40 metres long and weighed 80 tonnes; scientists weren't sure how such a big animal could even move. Only part of its skeleton has ever been found, but from the leg and the vertebrae researchers have managed to digitally piece together how the rest of it may have looked.



The team used this digital skeleton to reconstruct the dinosaur's muscles – soft tissue like muscle is almost never found in the fossil record. They then inputted this digital reconstruction of muscle and bone into a supercomputer where, over the course of a week, it learnt to walk.

'Given enough time on a big enough computer the dinosaur model learns to walk, and the nice thing is that all we have to tell the computer is "get from A to B using as little energy as possible," because that seems to be what animals mostly try to do. Then the computer will calculate a locomotive pattern that satisfies it,' says lead researcher Dr Bill Sellers of the University of Manchester.

Sellers and his team found that the dinosaur walked as expected, but that other activities such as getting up from lying down, or mating, would have been very challenging.

'We think it's right at the limit of what is possible. It's about as big as you can get without drastically changing its body shape,' Sellers says. It's possible that ligaments and tendons played an important role, perhaps locking in place so the dinosaur could stay upright without constant muscular effort, but evidence for these structures is rarely found in the fossil record.



Arctic sea-ice volume shows recovery

The latest satellite data suggest that a bounceback in Arctic sea-ice extent seen this summer compared with last is also mirrored in the volume of ice.

Data from the European Space Agency's Cryosat mission show there was more sea ice in the Arctic at the end of summer 2013 than at the same time in 2012.

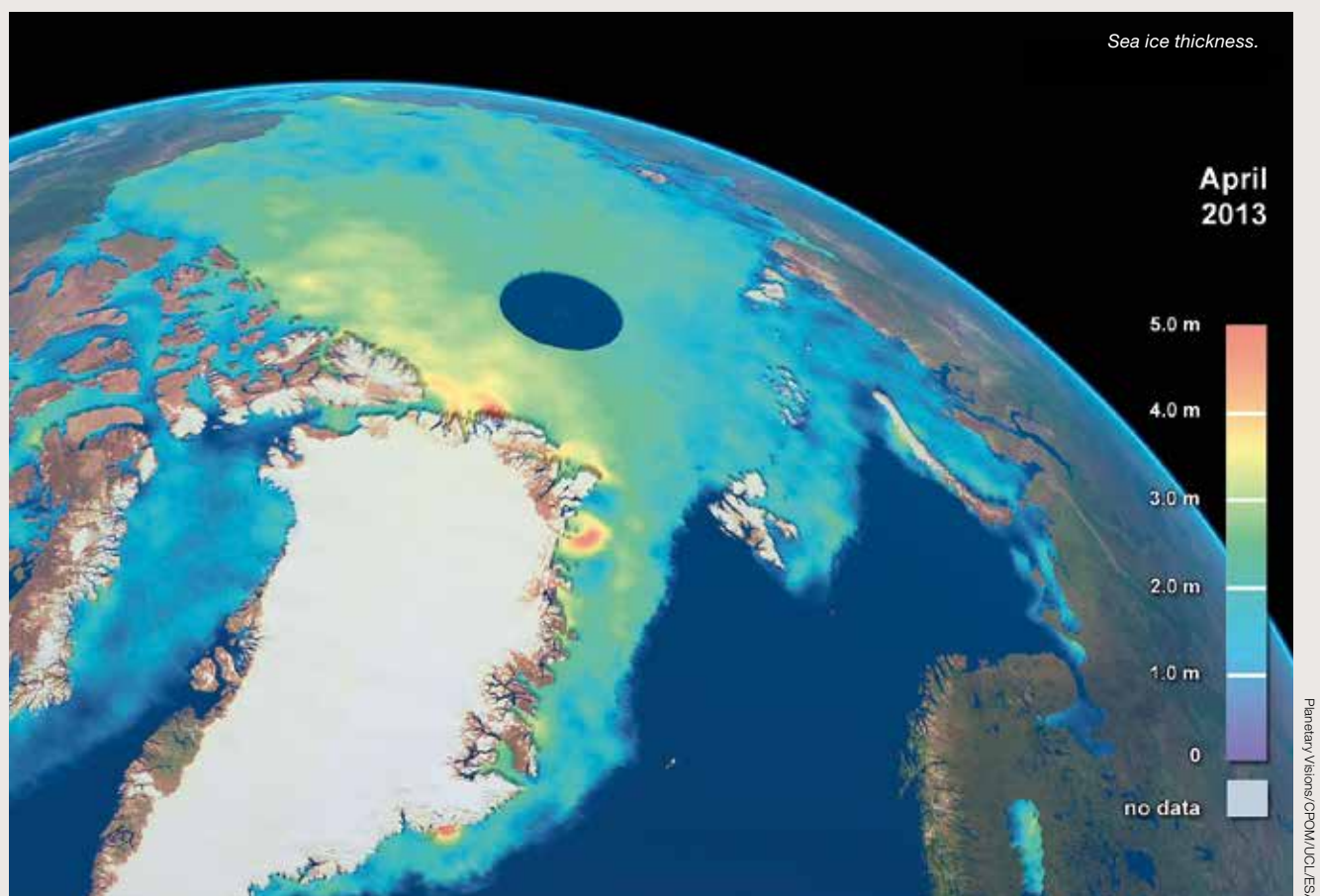
In October 2012, the month after sea-ice extent and volume are at their lowest, data from the satellite show around 6000km³ of sea ice. Fast forward to October 2013, and this had increased to 9000km³.

It seems about 90 per cent of this is down to growth of so-called multi-year ice – the sea ice that survives through more than one summer.

'Multi-year ice is generally believed to be a good thing, as it means that the ice pack is older, thicker and more resilient. Growth of multi-year ice suggests that melting this summer was relatively mild, or that snowfall or freezing last winter were harsh,' says Professor Andy Shepherd of the Centre for Polar Observation and Modelling (CPOM) at University College London (UCL).



He cautions against celebrating, though. 'Although 2013 has seen a 50 per cent increase in volume over the 2012 minimum, this has to be considered against the backdrop of long-term change. 2013 still ranks among the lowest volumes in the past 30 years.' In the 1980s, volumes were often around 20,000km³.





It's not every day you get invited into one of the world's most secretive states. But that's precisely what happened to seismologist Dr James Hammond. Alex Peel spoke to him about what it's like to work on the Earth's most enigmatic volcano.

Science without borders

A thousand years ago, it was responsible for one of the largest volcanic eruptions in human history. It left a four-kilometre-wide hole in the east-Asian landscape and a thick blanket of ash over the Korean peninsula and beyond. But until a couple of decades ago, only a handful of people knew it even existed.

Mount Paektu volcano straddles the boundary between two of the world's most secretive states – China and North Korea. It's showing signs of life, and its hosts are worried. So much so that a few years ago North Korea, normally so closed to the outside world, made a call for international help.

'It was all a bit serendipitous,' explains NERC fellow Dr James Hammond, who received the call through a complex chain of indirect contacts. 'We got about two weeks' notice before we had to be out there. I was a little bit nervous, as I would be going anywhere, but it seemed like a great opportunity to work somewhere that is fascinating both from a geological perspective and culturally.'

The Imperial College London researcher and his colleague, Professor Clive Oppenheimer of the University of Cambridge, had worked together in challenging conditions before, on volcanoes in Eritrea, Ethiopia and the Philippines. The experience would stand them in good stead.

'It required a lot of planning; more

planning than I've ever done for a trip before,' says Hammond. 'A lot of trust had to be built up in advance and communication was hard at times – I once had to go out to Pyongyang to discuss something because talking over the internet or phone is difficult.'

'The international sanctions were probably the biggest challenge. We were taking very specialist and sensitive equipment, and we had to get it all approved by both the UK and US authorities, which eventually delayed the project by a year. But there was a strong will on both sides and, ultimately, that's what made the project possible.'

On their first trip to North Korea, Hammond and Oppenheimer were shown around the volcano before sitting down to discuss things with their Korean counterparts. It was clear that they were worried.

Chinese scientists on the other side of the border had been monitoring the volcano with GPS, and had seen it begin to bulge upwards and outwards. Both sides had also been recording ever more earthquakes at the site, hinting at growing activity beneath the surface.

But the history and inner workings of the volcano remained a mystery. 'It's quite an enigmatic volcano,' says Hammond. 'Previous eruptions there are not well characterised, because it's such a poorly-known volcano. It's not directly related to a

plate boundary and its underlying dynamics are a bit of a puzzle.'

Some scientists have suggested it's related to a hot spot, where plumes of hot rock rise from deep within the Earth bringing volcanism to the surface. Others have proposed that it's the result of tectonic activity 600 kilometres below the volcano, where the Pacific plate is sinking slowly into the Earth. 'There's no clear evidence for either at the moment,' says Hammond.

The team came up with a project split into two parts. Hammond is mainly concerned with trying to work out what's going on inside the volcano. The specialist equipment that proved so difficult to get into the country is being used to monitor earthquakes on and around Mt Paektu which, together with very distant earthquakes, help the scientists to piece together what's going on beneath the surface.

Oppenheimer is looking at the geology. 'This will hopefully tell us more about the history of the volcano,' explains Hammond. 'We know about the so-called millennial eruption [the one a thousand years ago], and it's been suggested that there have been other eruptions since, maybe even as recently as 1903. But they're not well catalogued.'

Korean scientists have been hampered in their efforts to understand the volcano by a lack of access to the outside world. But Hammond is impressed with his colleagues.



‘It’s difficult for the Korean scientists,’ he says. ‘They don’t have access to all the latest papers and science, and it is tricky for them to get to conferences, which are invaluable from an academic perspective. But their understanding is strong and their background is good.’

‘Arriving at seismic monitoring sites that were already built was a bit odd, but they were incredible – far better than anything I could have built.’

He believes there are signs that, in science, North Korea could be opening up a little. ‘We recently did a joint presentation in Japan. The Koreans couldn’t attend, which was a shame, but their names do appear on the research.’

‘Science is in a unique position here because it’s so apolitical. We’re looking at a volcano that people are worried about – we’re worried about it, and so are the North and South Koreans, Chinese and Japanese.’

The seismic stations will remain in the ground for another year. Hammond and Oppenheimer have ambitions of welcoming their Korean colleagues to the UK to go through the data. The aim is to have the work published in international scientific journals, which would be a first for North Korean scientists.

Ultimately, though, the unlikely partnership is united by the shared purpose of understanding the character of the volcano and what sort of risks it poses.

After all, those risks may also be shared. ‘With volcanoes of this size, the ash can have an influence on the global climate, and we all saw what happened to airspace with the much smaller Icelandic volcano in 2010,’ says Hammond. ‘It’s in all of our interests to understand this one.’

i Dr James Hammond is a seismologist in the Department of Earth Science & Engineering at Imperial College London. To learn more about his work, see www.imperial.ac.uk/AP/faces/pages/read/Home.jsp?person=j.hammond



Mapping marine sand and gravel

Aggregates – sands and gravels – are essential for building and maintaining our houses and infrastructure, so we need to be sure we have a reliable supply. Tom Bide and Joseph Mankelow explain how geological mapping is taking us in the right direction.

Aggregates are a range of coarse particles that add strength to building materials and are widely used for foundations and drainage. The term includes recycled building materials like concrete, but the raw material comes from geological deposits of sand, rock and gravel.

They may not be beautiful, but aggregates are the most mined materials in the world, both on land and at sea. Demand for these offshore mineral resources is only likely to increase in the UK, as elsewhere, with major new infrastructure projects ranging from housing to coastal defences.

Marine aggregates are extracted by dredging – sand and gravel are sucked up a pipe trailed along the sea floor, normally 10 to 40 metres below the sea surface. These

specially designed vessels vary greatly in size, but large ships can extract up to 2600 tonnes of sand and gravel an hour and hold up to 8000 tonnes of material. The UK has one of the largest dredging fleets in the world, providing important resources for its construction sector, which is valued at £120 billion per year.

Major urban areas on the coast or on navigable rivers, such as London, particularly benefit from marine aggregates as they can be landed at wharves very near to the market, avoiding the energy and other impacts of long-distance road transport from inland quarries. Half of all construction aggregates used in London come from the sea.

Demand for aggregates is growing, but so are other demands on the seabed, for example from fishing, oil and gas pipelines

and renewable energy installations. If the supply is interrupted, rising aggregates prices would have a direct impact on the UK's plans for growth. So it is more important than ever that our offshore aggregates are managed effectively and their extraction is carefully planned.

While the environmental regulations and restrictions on aggregate extraction are well established, a new planning system has been implemented for UK waters to reduce conflict over space on the seabed while protecting marine ecosystems. The Marine and Coastal Access Act 2009 and the Marine (Scotland) Act 2010 specifically outline the need to safeguard mineral resources to ensure future supplies, an approach which is already well established in onshore land-use planning. A new body, the Marine Management Organisation (MMO), has been tasked with balancing different uses of the marine environment

offshore England, while the Scottish and Welsh governments are responsible for this task in their respective marine areas.

The MMO issues environmental permits for dredging and is drawing up spatial plans to ensure dredging activities are balanced against other national and regional activities. To do this, they need a clear picture of where the UK's aggregates resources are, and which are the most economically valuable and viable. So BGS was commissioned by the Crown Estate (which holds the rights to all non-energy mineral resources on and under the UK Continental Shelf) to map the distribution of UK marine sand and gravel.

Mapping the resource

Marine aggregates have similar origins to their onshore counterparts, and are the products of glaciers and rivers at a time when the sea level was much lower and the

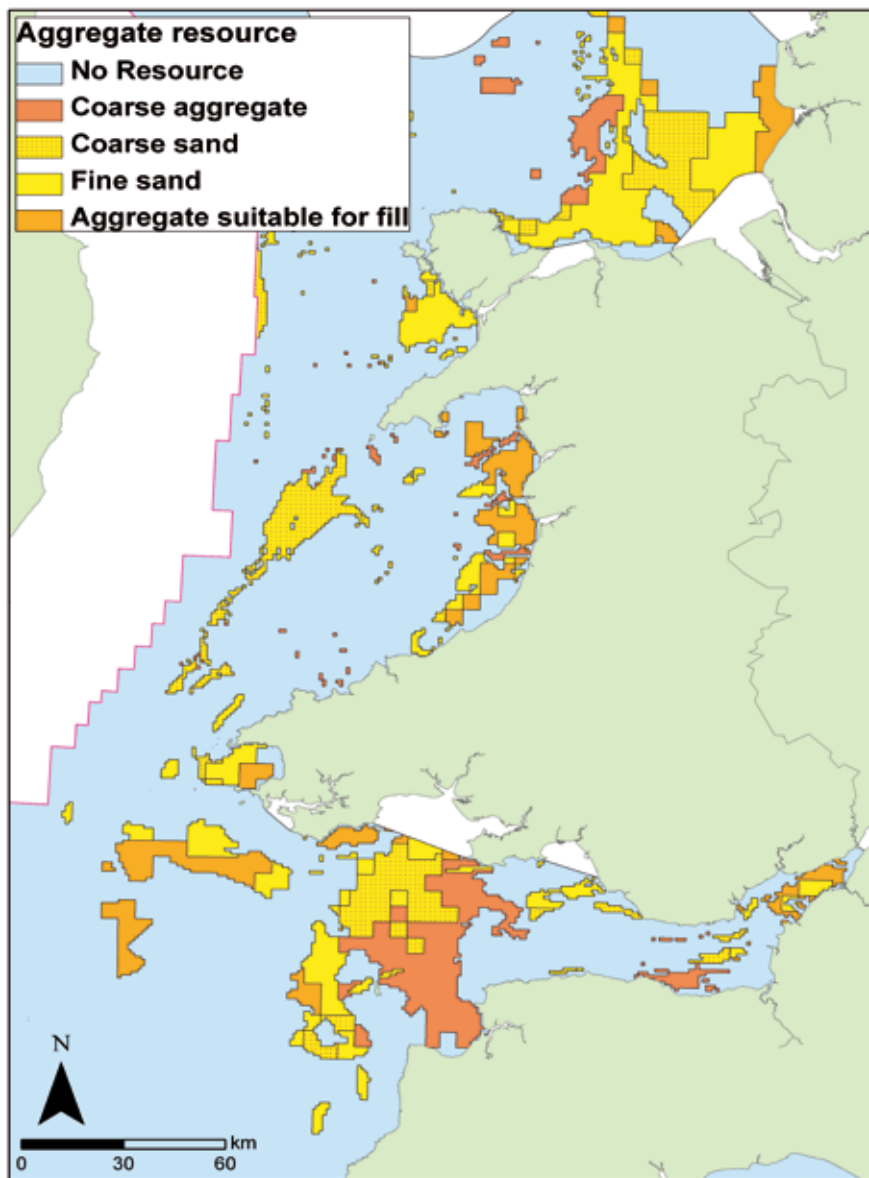
UK coast extended far out into the sea. Many of these deposits are often covered by more recent marine sediments and working out where they now lie requires a high degree of geological interpretation, using borehole information, geophysical data and modelling.

Producing the maps didn't require new geological survey, but rather a lengthy desk-based exercise to combine information from all BGS existing sources of information. This included a series of 165 offshore geological maps, a database of almost 95,000 seabed sediment samples and seismic data taken over more than 350,000km of seabed, as well as data gathered for more recent regional studies.

All these data sources were combined digitally to produce a model of sand and gravel resources. These can be widespread but are not always present in sufficient concentrations to be extracted economically. So aggregate resources were defined as areas where the sediment was thick and had low mud content compared to the sand and gravel. Areas of coarse sand were identified from the average grain size; this is particularly important because coarse sands are currently in high demand for concrete but are in short supply onshore.

The results are presented as four regional maps: English Channel and Thames Estuary; Welsh Waters and the Irish Sea; East Inshore and East Offshore Marine Plan Areas; and Scottish Waters and the Central North Sea. They are already having a direct impact on the planning process. For example in its plan for the East Inshore and East Offshore area, the MMO has earmarked for protection important deposits – such as the coarse sand needed for concrete – that BGS has identified.

These data on mineral resources mean the new planning process can help ensure the UK balances its need for a steady supply of these essential raw materials with the need to protect fragile marine environments.



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The maps and accompanying reports can be downloaded from www.thecrownestate.co.uk/energy-infrastructure/aggregates/

NERC PhD student photo

In late 2013 NERC launched a competition, inviting the doctoral students we support to send us photos that show some aspect of their research, along with short articles on their experiences doing it.

The results were by turns beautiful, horrifying, dramatic, uplifting, illuminating and funny – sometimes all at once. On this page is the winning picture and the second- and third-placed entries are opposite; on our back cover are just a few of our favourites among the other entries.

There were far too many highlights to reproduce them all here, but you can see more entries online:
<http://planetearth.nerc.ac.uk/multimedia/story.aspx?id=1561>

1 Burying beetles process an animal carcass.

*Paul Hopwood,
University of Exeter*



Photography competition



2 Eruption in the central crater of Mount Etna in Sicily.

Robin Wylie, University College London



3 Field research in the wind, Tierra del Fuego, South America.

Christopher Darvill, Durham University



Getting caught in one of the biggest floods Cambodia has seen in years wasn't part of Chris Hackney's fieldwork plans – but it turned out to be a great opportunity for scientists to learn how rivers behave in extreme conditions.

Riding the crest of the flood wave

After two hours cramped under a tarpaulin, attempting to avoid the worst of the monsoon, I was starting to doubt I would ever dry off.

We had managed four days of fieldwork before we encountered any rain in Cambodia, but now near-zero visibility meant it was no longer safe to navigate on the Mekong River, and all work ceased. So here I was, hunkered down beneath a cover in a feeble attempt to keep myself and the equipment dry.

For about a week and a half after that point we were at the mercy of the annual monsoon and Typhoon Usagi, which made landfall in the northern part of the Mekong catchment, adding even more water to an already swollen river. Little did we know that we were soon to be caught up in one of the Mekong's largest floods.

At its peak, 63,000 cumecs (cubic metres per second) was flowing down the river. By comparison the largest flood recorded

on the River Severn in the UK is 753 cumecs.

So, why was I sitting in a boat during the monsoon? The answer is that I was part of a fieldwork campaign doing research for the NERC-funded STELAR-S2S (Sediment Transport and Erosion in Large Alluvial Rivers – Source to Sink) project. This aims to understand the relationship between climate and sediment transfer on the Mekong – one of the Earth's largest rivers.

Every year, the world's major rivers carry around 19 billion tonnes of sediment to their deltas, which are home to around 14 per cent of the global population. Most deltas are under threat not only from rising sea levels, but also from dwindling supplies of the sediment needed to maintain them. If these supplies are cut off, large areas of land could be lost over the coming century. Most of this sediment is transported and deposited during the annual monsoonal floods, and their timing and magnitude are being



Flooding in Kratie, Cambodia.

Amelia Paszkowski

affected by climate change as well as by human development, in the form of dams to provide hydro-electric power.

Along the Mekong, several such dams are currently being built, or have been planned for construction in the near future. Furthermore, the Mekong's delta is one of only three in the world classified by the UN Intergovernmental Panel on Climate Change as 'extremely vulnerable' to future changes in climate. The STELAR-S2S project aims to provide the first quantification of the natural and human influences on sediment supply and deposition under changing climates. It is uniquely placed to consider the impacts dam construction will have on sediment transfer within the Mekong system.

The project is a collaboration between the universities of Southampton, Hull and Exeter in the UK and Illinois in the USA. For three weeks in September our team deployed high-resolution depth and flow surveying equipment along a 300m stretch of the River Mekong in Cambodia. The bathymetric data on the shape of the riverbed revealed 4m-high sand dunes within the main channel. By surveying these features every few hours we could track their movement downstream, and hence measure the amount of riverbed material being transported.

Later fieldwork will repeat these surveys, letting us see how much sediment the river is carrying at different times of the year; this will give us an idea of how important these flood cycles are in transporting sediment.

Measuring all the way to the bank

As well as the riverbed, we also surveyed the submerged parts of the banks in order to characterise their roughness. Our earlier work has already shown that the roughness of a riverbank can make an important difference to how fast it erodes. Bank erosion can deliver large quantities of sediment into the river, helping maintain the flow of sediment to the delta further downstream.

To understand more about how the Mekong's banks erode, we made detailed measurements of the flow of water near them, revealing complex patterns of behaviour that had never been identified before in large rivers. Specifically we are interested in how major events, such as the annual flood, affect the type and intensity of bank erosion and floodplain sedimentation in large rivers. Are the processes experienced around the riverbank different at the peak of the flood compared



Steve Darby

to periods of low flow? Or is it the changes in water level before and after the flood peak that erode the banks most?

The fieldwork's timing, coinciding with the 2013 flood peak, meant we could also gain unique data on the behaviour of a series of splay complexes – fans of sediment that are deposited by channels running off the main-stem through breaches in levees. These channels transfer large amounts of sediment and water to the floodplain, and are only active during high flows.

By monitoring how the water flows over these features and sampling the type and amount of sediment moving onto the floodplain, we hope to shed light on how these features connect the floodplain to the main channel.

We are now planning a further field season later in the year to retrieve sediment cores from these systems, once the flood waters have receded. This will let us analyse sedimentation rates and record the internal structure of the splay complexes. This in turn will mean we can see how these features have developed over time and link known flood events to individual layers of sediment. Eventually we want to understand if, and how, large flooding events deposit sediment on the floodplain.

All this data will ultimately enable us to say how large rivers like the Mekong respond to annual monsoonal floods. By quantifying the amount of sediment being

generated through bank erosion and passed through to the delta, as well as the amount deposited on the floodplain, we will be in a position to understand how climate change and dam construction will affect the Mekong delta.

This could influence future dam designs so that they let enough sediment pass through to maintain delta construction – not only in the Mekong, but in all large rivers. We also hope our findings will allow local governments and intergovernmental institutions such as the Mekong River Commission to give better protection from riverbank failure to local communities and infrastructure.

By the end of the trip it began to sink in just how lucky we had been – this turned out to be a career highlight for everyone involved. Not only have we learnt so much about how large river systems behave and respond to extreme events; we also have first-hand experience of what extreme events look like, and how they affect the local environment and people. The team will head back out in 2014 to repeat the surveys – hopefully in drier conditions than before.



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More information on the STELAR-S2S project can be found at

www.stelar-s2s.org Twitter: @stelar_s2s



Tergivelum cinnabarinum.

Mid-Atlantic crossroads

Scientists have found an unexpected wealth of life more than two kilometres down in the mid-Atlantic. Monty Priede describes the ECOMAR project's voyages of discovery.

Halfway between Iceland and the Azores, the vast North Atlantic Current – an extension of the Gulf Stream with over 100 times the flow of the River Amazon – crosses the Mid-Atlantic Ridge through the Charlie-Gibbs Fracture Zone and its 4km-deep canyons.

This current defines the sub-polar front, where cold waters from the north meet warmer waters arriving from the south. This results in a zone of high biological productivity, with plenty of food for fish and other animals. Together with the complex of undersea mountains and valleys, this creates a special mid-ocean habitat. The ECOMAR (ECOsysteM of the Mid-Atlantic Ridge) project, which I led, studied this area for six years.

The project began in 2007 with a voyage

of the newly commissioned RRS *James Cook* to map the sea floor. The 3D sonar display revealed a detailed pattern of terraces, cliffs, slopes and plains that no one had ever seen before. We had imagined that the Mid-Atlantic Ridge – the place where the Eurasian tectonic plate meets the North American one deep under water – would be mainly jagged rocks. But the sonar and cameras we lowered beneath the ship showed that most of the sea floor was draped with pale-coloured sediment, like a fresh fall of thick snow. On slopes this was easily disturbed, creating avalanches and underwater blizzards that completely blocked the view from the camera.

In 2010 we took a really close look using the remotely-operated vehicle (ROV) *Isis*, and found that 2.5km down, the sediment

surface was marked by burrows, tracks and imprints of numerous animals including sea cucumbers, starfishes and burrowing worms, all thriving on the organic detritus falling from the surface. Analysing the videos, we found 58 different types of animal trace. The most extraordinary were the casts left behind by acorn worms, which we saw taking sediment into their mouths using their wide lips and expelling it from their guts like toothpaste trailing behind on the sea floor.

These deep-sea acorn worms, which are free-living unlike their burrowing shallow-water cousins were only discovered this century. They are very primitive relatives of the vertebrates, having split off at a stage of evolution before backbones, limbs, tails, brains and eyes appeared. It was amazing

Deep-sea jellyfish.



Sea cucumber.



Both images: David Shale

The greatest satisfaction came from small things like seeing a jellyfish delicately feeding above the sea floor, or bagging three new species before breakfast.

to see these very basic creatures, never captured before in the Atlantic Ocean, thriving in large numbers on the sea floor.

We found two new species – a pink one to the north of the sub-polar front that produces spiral traces, which we called *Tergivelum cinnabarinum*, and a purple species to the south, *Yoda purpurata*, that produces wavy traces. These animals are adapted to the different kinds and qualities of food falling from the surface on either side of the front.

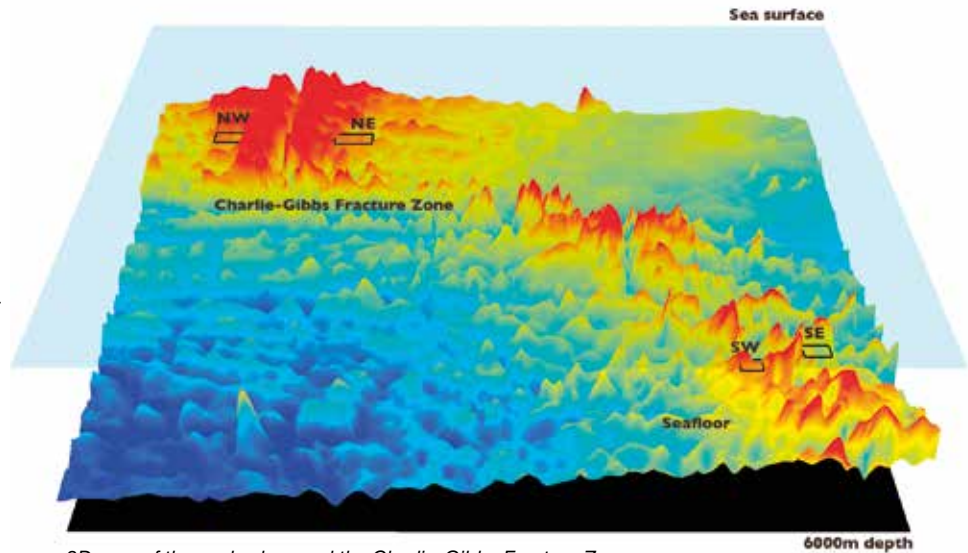
On the sea floor there were no tracks from these worms moving from one feeding site to the next. We saw that they could float off the sea floor and drift on the currents to a new feeding site. Sea cucumbers, which forage in a similar way by crawling on the sea floor, also turned out to use this floating trick.

Gardens of the deep

Although statistics indicated that rocky cliffs and outcrops accounted for less than 5 per cent of the area and could be ignored in our calculations, we could not help but be attracted to the rich covering of sponges, feather stars, anemones and corals reaching out from the rock surfaces to capture any passing food particles.

We tried switching off *Isis'* lights to observe natural light from bioluminescence, and came across bamboo corals on a cliff face which produce bursts of light whenever they are touched. The technical team on board the *James Cook* made a special tickling stick which was fitted to the ROV's manipulator arm, and with this we managed to stimulate remarkable light displays from the coral. The function of this light display is unknown, but all the fishes living at this depth have eyes despite living far below the reach of any sunshine from above, so we know it has an audience.

Using trawls on the flat terraces of the Mid-Atlantic Ridge, we captured 22 species of bottom-living fish – all ones that are found at the same depths on the continental slopes around the edges of the Atlantic. Genetic studies indicate that these populations are closely connected, even when they live on different sides of the ocean.



3D map of the seabed around the Charlie-Gibbs Fracture Zone.

The sub-polar front is just as important for birds as for fish and other underwater dwellers – for many of them, Charlie-Gibbs is not a remote offshore outpost, but an integral part of their normal foraging range. For example, satellite-tagging a male northern fulmar in the Orkney Islands north of Scotland revealed that it left its mate incubating eggs and flew to the area in a 6000km, 15-day excursion before resuming its parenting responsibilities back on the nest.

This bird proved to be a regular visitor – indeed, at sea we observed over 300 northern fulmars at a time around the ship, together with 15 other bird species, three species of dolphin and four of whale. The bird from Orkney had found its way by following the clouds and weather patterns marking the sub-polar front until it reached the Mid-Atlantic Ridge. For many marine species, Charlie-Gibbs is a clearly signposted mid-ocean crossroads.

The ECOMAR team established four observatories in the Charlie-Gibbs area; from 2007 to 2010 these continuously monitored currents, temperatures and organic matter fall-out from the surface. We used satellites, towed nets, set traps and measured everything we could from the surface to the sea floor to work out the complex food chains sustaining the region's ecology. Yet the greatest satisfaction came from small things like seeing a jellyfish

delicately feeding above the sea floor, or the day we bagged three new species in one hour before breakfast.

In 2010 under the auspices of OSPAR (Oslo Paris Convention), 15 European nations established the Charlie-Gibbs Marine Protected Area to conserve the region's biodiversity and manage human activities. The ECOMAR project results are important for understanding this biodiversity, and will aid future decisions on how to manage it, but we have only studied a small percentage of the area and much remains to be found.

Named after the first survey expeditions to the area, the Charlie-Gibbs Fracture Zone was first discovered in the 1960s but is now a very conspicuous feature on modern digital maps of the globe – you can even see it on the moving map displays provided for passengers on transatlantic passenger aircraft. Next time you see Charlie-Gibbs on the map, spare a thought for the amazing creatures there.



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Peatlands of the western Amazon

Recent investigations in western Amazonia have revealed vast peatlands, up to 8m thick in places. Because they are so remote, we know little about them compared to peatlands in the northern hemisphere. Tom Kelly and Freddie Draper explain how their work will help us understand these ecosystems and reveal how big they really are.



Mauritiella palm pollen.

From floating mats of grasses and sedges, to diverse flooded forest and palm-dominated swamp, the pollen tells a tale of ecosystem changes.

Seen from space the Amazon River winds like a silk ribbon from the Andes to the Atlantic. Here, it delivers a fifth of the freshwater that enters the world's oceans. Along its length beneath feathery palm fronds, in old channels carved out by the river, lie some of the most substantial peatlands in the tropics. Some of these are many kilometres long, the size of small towns, and like small towns they have their own colourful inhabitants.

Macaws nest in dead palm trunks, hummingbirds feed from the white trumpet flowers of peatland trees, and tapirs and monkeys feast on the red armoured fruit of *Mauritia flexuosa*, often the dominant species of palm. People also prize this fruit, as it contains high levels of essential beta-carotene; in the city it is even made into ice cream.

Like all peatlands across the world, those in Amazonia store carbon. Plants take carbon dioxide from the air and use the carbon to build their leaves, roots and branches. When they die, this carbon is stored in the peatland's layers of organic material. These build up over time, since water-logging means that there is little oxygen and so decay is very slow. By removing carbon dioxide from the atmosphere and storing it for long periods, peatlands have the potential to help slow man-made climate change. But if they are damaged, for example by drought or deliberate drainage, they can also release that stored carbon back into the atmosphere.

Over the last few years, our group at Leeds has been trying to learn more about Amazonian peatlands. Collaborating with colleagues from the Instituto de Investigaciones de la Amazonía Peruana at Iquitos in Peru, we have set out to answer some basic questions: how do Amazonian peatlands work, what controls peat accumulation, and how are they changing?

The Amazonian climate already seems to be shifting, with less rain falling during the dry season and more in the wet season, creating greater climatic variation and some extreme floods and droughts over the last few years. To try to understand how peatlands might respond to these changes, we can use their current hydrology and ecology as well as their past behaviour as a guide.

In 2011 and 2012 we set out to undertake the first detailed hydrological study of an Amazonian peatland at a site named Quistococha, meaning Christ's lake, close to the city of Iquitos. We measured how quickly the water flows

through the peat and then, back in Leeds, used numerical models to help understand whether this might be important for its behaviour. If a peatland drains quickly when the moisture source is switched off it means that the carbon stored there is more vulnerable to release during dry conditions, as oxygen can reach the peat in the upper layers and cause fast aerobic decay.

Where does the water go?

Our results were surprising: water flows very quickly through the peat by comparison with many northern peatlands, but the models show that even this rapid flow is not enough to shed a lot of the water entering the peatland each year from the heavy rain that falls in the western Amazon. A large proportion of the water must leave the peatland by travelling up and out through the tree leaves, a process known as evapotranspiration.

So it's clear that vegetation must be important to how Amazonian peatlands function today, as it helps to determine the degree of water-logging as well as the nature of the organic matter contributed to the accumulating peat. To understand how peatland behaviour might change over time, we need to know how the vegetation has changed in the past, and why.

To discover a peatland's history, it is possible to look at the plant remains in samples going down through the peat; the deeper you go, the further back in time. The pollen and spores produced by plants are virtually indestructible except when exposed to the air, so pollen in lake sediments and swamp peats can be preserved for thousands of years.

The first pollen record for Quistococha extends 2300 years into the past and shows that the peatland vegetation has completely changed several times during this period. From floating mats of grasses and sedges, to diverse flooded forest and

palm-dominated swamp, the pollen tells a tale of pronounced ecosystem changes caused by shifts in the course of the river and its flooding regime. Their history is inseparable from that of the dynamic rivers that characterise this landscape. It also appears that although these peatlands may not be as diverse as a non-flooded rainforest at any one point in time, over the course of thousands of years they host a wide array of different species and habitats.

Our research group plans to continue building on our knowledge of Amazonian peatland ecosystems by combining vegetation census and pollen work with hydrological and geochemical analyses to develop a more detailed understanding of these landscapes' function and sensitivity. This will help us predict how they are likely to respond to future environmental changes.

We will also be drawing on images of the Amazon from space, which are scientifically valuable as well as beautiful. Satellite data will let us extrapolate from our observations of patterns and processes at individual sites to the whole Amazon basin and understand the role that the region's unique peatlands play in the global carbon cycle.

i

Tom Kelly and Freddie Draper are PhD students in the School of Geography at the University of Leeds. The project 'Long-term Forest Dynamics of Peruvian Amazonia' is led by K. Roucoux, I. Lawson and T. Baker. See www.geog.leeds.ac.uk/projects/ltdf for further information. The work was carried out in collaboration with colleagues in Peru.



Esme Statlock

Our lakes are not just objects of beauty – they play a vital role in our ecosystems, supporting life on Earth. Stephen Maberly and Ian Jones introduce some new technology that will tell us what's happening in our lakes and help keep them in top condition.

Networking to protect our freshwater lakes

The station on Llyn Tegid, Wales.



Lakes across the world are often in areas of outstanding natural beauty, enriching the landscape and our lives with their serenity. But they also play an important role in supplying us with water, food, energy, flood control and recreation. They often support a tourist industry that can be vital to the local economy; for example 15 million people sample the delights of the English Lake District every year.

Since the industrial revolution and the increase in human population, many lakes in Western Europe and elsewhere have suffered from the effects of sewage and fertilizer running off farmed land, which not only affects their economic value but also causes severe ecological damage and the loss of plant and animal species. Nowadays improvements in waste-water management and farming practices have started to reverse these effects at many lakes, but recovery is often slow and other environmental pressures such as climate change, invasion of non-native species, high water abstraction and pollution from the atmosphere are exacerbating the problem. One particular issue is algal blooms, large surface scums of cyanobacteria (blue-green algae) that thrive on excess nutrients – nitrates and phosphates – in the water but also benefit from climate change. These blooms are widespread in many lakes around the world and since they are potentially toxic to livestock, pets and humans they severely restrict how the lake can be used.

To understand how best to manage these threats and to forecast how lakes will respond to future environmental conditions, we need to measure lake responses to environmental change at appropriate time scales. The condition of a lake can change quickly – caused by rapid growth rates of algae, and the effects of short-term weather events such as storms and floods, or periods of hot weather – so frequent measurements are needed to understand and forecast lake responses to change.

The network and monitoring system

As part of the NERC Network of Sensors programme, the UK Lake Ecological Observatory Network (UKLEON) has developed an innovative way of capturing all that information. It involves a network of 11 automatic water-quality monitoring stations (AWQMS) at lakes in Wales, north-west England, Scotland and Northern Ireland covering a variety of lake types and sizes. This currently represents



Changing batteries on Round Loch of Glenhead.

the greatest density of high-frequency lake-monitoring in the world. Each AWQMS has meteorological equipment to record local weather, and a chain of underwater sensors measuring temperature at a range of depths. As well as these physical parameters, each station now also measures a wide range of chemical and biological variables. At the surface there

The whole network produces more than 43 million data points every year.

are sensors measuring conductivity, pH and the concentration of carbon dioxide and dissolved oxygen. Other sensors measure the concentration of chlorophyll *a* (the green pigment in all photosynthetic algae and plants) and phycocyanin (a blue pigment found in cyanobacteria). Finally, there are sensors to compare the light levels under water with those just above the surface.

Even with fortnightly servicing, the sensors can become colonised by bacteria and algae, but these are removed using automatic wipers. The stations are

principally powered by rechargeable lead-acid batteries; but some of the lakes in the network are very remote and regularly transporting a set of heavy batteries is no mean feat, so solar panels have been installed to top the batteries up throughout much of the year.

Teams of technicians, scientists and students visit each site, braving the elements to deploy, calibrate and maintain the sensors. All this effort means that each AWQMS now records around 30 different variables every four minutes, so the whole network produces more than 43 million data points every year – far more information than it was previously possible to acquire.

However, handling, quality checking and using such a mass of data are huge technological challenges. Drawing on the expertise of data specialists from the UK Astronomy Technology Centre and the UK Environmental Change Network, the project has developed its own solution in the shape of a bespoke piece of software that automatically collects the information sent from each buoy and loads it into an Oracle database held at the Centre for Ecology & Hydrology (CEH) at Lancaster.

The database runs simple quality checks by flagging any data that are out of the ordinary in any way, for example if a measurement lies outside the expected range, or was gathered when the battery was low or when sensors were being serviced. No data are discarded, so a user

can decide how to deal with such issues. For users who don't need very high-frequency data, the database automatically produces hourly and daily averages for all the variables measured.

We have set up a website where anyone can view the data, either in real time or for past periods. Users can look at one particular site or type of measurement, and can compare a given measurement – water temperature or solar radiation for example – across the whole network (see link below).

While the data have numerous potential applications, the UKLEON project is focusing on using them in three specific areas: forecasting algal blooms as they begin to develop, using the *in situ* measurements, short-term weather forecasts and a model to predict the growth of phytoplankton; studying the effects of the weather on carbon cycling in lakes, since whether lakes are carbon sinks or carbon sources depends in part on weather conditions; and using these high-frequency measurements to determine how similarly lakes in each region respond to weather conditions, so that results can be extrapolated beyond the 11 lakes in the network.

It's early days but the network represents a big step forward in our ability to monitor the environment in the detail we need. It's a huge advantage for scientific research and it has the potential to provide environmental managers, water companies and other businesses with up-to-date information that will increase their efficiency and help to look after the environment.

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UKLEON is led by CEH in collaboration with the universities of Glasgow, Lancaster, Loughborough and University College London, with additional scientific support from Natural Resources Wales and the Agri-Food and Biosciences Institute, Northern Ireland. For more information about the project including details of other partners and contributors, and to view the online data, see www.ceh.ac.uk/sci_programmes/water/uk-lake-ecological-observatory-network.html

Dr Ian Jones is a lake physicist in the Lake Ecosystems Group based at CEH Lancaster and Professor Stephen Maberly is an expert in lake ecology and head of the Lake Ecosystems Group.

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Taking the air

Understanding our background atmosphere

Getting a clear picture of what the atmosphere is like in remote places is just as important as understanding local air pollution levels. Anna Jones and colleagues explain how a global network of monitoring stations is giving us more of the information we need.

The chemical composition of the atmosphere is something that affects us all profoundly. It defines the quality of air that we breathe, the health of the ozone layer, and influences the temperature balance of Earth's climate. So understanding why the atmosphere behaves as it does is of fundamental importance to everyone.

In general terms, we gain our understanding from measurements of the chemical constituents found in the air which can tell us how the atmosphere is changing in both time and space. We interpret these measurements using numerical models which simulate the global atmosphere, and which include information about air-mass movement, sources of chemicals to the atmosphere and chemical reactions.

Most observations of atmospheric composition are made in cities or suburbs

and are used to support national policies for controlling urban pollution. Less common but equally important, though, are measurements made in remote areas where few people live and where there is little intense agriculture or industry. These measurements have a different purpose: they give a broader view of global changes in Earth's atmosphere and establish the baseline of atmospheric composition – the so-called 'background' atmosphere.

In remote locations, variations in atmospheric composition can be caused by large-scale changes in man-made emissions, in weather circulation patterns, or from variations in natural processes (for example changes in vegetation or emissions from the ocean). A central challenge from background measurements is to work out which changes in atmospheric composition are a result of human activity and which are natural, something which

can be achieved with the help of numerical models. Importantly, these changes tend to occur gradually, over years or decades, so to detect them we need to take measurements over the same long periods.

We monitor the background atmosphere in a number of ways including measurements from satellites, aircraft and balloons. The most accurate, however, are long-term measurements of atmospheric composition made on the ground from atmospheric observatories. These surface measurements are considered the gold standard against which other observations are compared. This is partly because they cover a long period of time, but also because they are made under optimum measurement conditions where the instruments are most likely to perform at their best.

So to truly understand what is occurring in the planet's remote places we need eyes

Cape Verde Atmospheric Observatory.





The UK currently operates two GAW 'Global' observatories. The Cape Verde Atmospheric Observatory (1) is in the tropical North Atlantic where it samples background marine air masses as well as air from the African continent. Halley Research Station (2) is the UK's polar atmospheric observatory and sits on the Antarctic coast where it is exposed to air masses from the Southern Ocean, the sea ice zone, and from inland Antarctica. A third UK observatory, the Auchencorth Moss monitoring site (3) in eastern Scotland, monitors UK/European air for trace gas and particle concentrations and applied for GAW 'Global' status in December 2013.

These three UK-operated background observatories collaborate to share expertise and experience of working in remote regions where access can be limited or impossible. We can also share some of the costs associated with tying our measurements to internationally-recognised measurement scales.

It's particularly striking that these three UK background observatories, Cape Verde, Halley and Auchencorth Moss, are operated by three different NERC research centres – National Centre for Atmospheric Science, British Antarctic Survey and Centre for Ecology & Hydrology respectively. This demonstrates how central atmospheric science is to the environmental challenges we face.

www.ncas.ac.uk/index.php/en/cvao-home

www.antarctica.ac.uk/bas_research/support/labs/caslab/index.php

www.ceh.ac.uk/sci_programmes/carboncatchmentsauchencorthmoss.htm

around the globe – a network of surface observing stations continuously measuring atmospheric composition. This capability is far beyond the resources of any single nation, so countries are joining forces to create the global networks we need.

The Global Atmospheric Watch programme (GAW), run by the World Meteorological Organisation (WMO), is the largest of its kind and brings together observations from hundreds of background measurement stations at remote locations around the world.

The WMO identifies what chemicals should be studied (for example greenhouse gases, reactive gases, or stratospheric and tropospheric ozone) based on their importance within the atmospheric chemical or climate system, and then invites participating observatories to contribute measurements. Many small observatories measure only one or two atmospheric components but a core of 29 worldwide have committed to a much more extensive measurement programme – these are referred to as the GAW 'Global'

observatories. They are scattered across every continent and on remote oceanic islands and are operated by both developed and developing countries, making this a truly international effort.

To have the widest benefit, data need to be easily accessible and free. The GAW data are available from public global databases and are the starting point for many modelling projects. It must also be possible to reliably compare observations made by different research groups, something which is achieved by careful instrument calibration. The WMO provides guidance on how to calibrate the data and tie them to internationally-recognised measurement scales.

The WMO also issues regular bulletins describing the state of the atmosphere. A recent greenhouse gas bulletin emphasised how predicting the evolution of these gases was critically dependent on the global network of surface measurements, an effort which has gained wide visibility following media reporting that atmospheric CO₂ had exceeded 400 parts per million.

So it's important to understand atmospheric composition and how it changes in time and space. We can't do this on our own, but by combining measurements from our unique locations with those made by other nations around the world, we can gain truly global perspectives on our background atmosphere – something which benefits us all.



Dr Anna Jones is an atmospheric chemist at the British Antarctic Survey. Dr Christine Braban is an environmental physicist at the Centre for Ecology & Hydrology and Professor Lucy Carpenter and Professor Ally Lewis are atmospheric chemists at the University of York.

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Global Atmosphere Watch
www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html

Secrets of Cornwall's metal-tolerant trout

A large brown trout is shown swimming vertically in clear, turquoise water. The fish is silhouetted against a bright, circular light source, likely the sun, which creates a strong lens flare and illuminates the water around it. The trout's fins are visible, and its body is elongated and tapers towards the tail.

Metal contamination is a problem in some UK rivers and can harm many freshwater organisms. But a population of brown trout in Cornwall's metal-contaminated River Hayle shows no obvious ill-effects. Tamsyn Uren Webster and Eduarda Santos investigated their apparent tolerance.

Cornwall has a rich history of mining activity. Cornish tin has been extracted and traded since prehistoric times and at the turn of the 19th century Cornwall had one of the richest mining economies in the world, producing copper, tin, arsenic, lead, zinc and silver. The industry brought great prosperity but some of its long-term consequences have not been so welcome. Though mining had declined significantly by the 20th century, a number of rivers and estuaries are still contaminated by the metals released by industrial processes.

The River Hayle is one of them. Concentrations of copper, zinc, nickel and cadmium are so high in this river they would normally be expected to be lethal to brown trout which, as a species, are particularly sensitive to pollution including metals. But the population of brown trout in the Hayle shows no obvious ill effects from these metals.

As environmental biologists interested in how fish respond to stress in their local environment, we wanted to find out what made these trout so different. To do this, we caught brown trout from the Hayle and from a relatively clean river, the Teign, and measured how much metal was present in the liver, kidney, intestine and gills of the fish from each river.

In fish, like in other vertebrates, the kidneys and liver are very important for storing, detoxifying and eliminating metals and other toxic substances. Our results showed that, on average, the concentration of metals (including zinc, copper, nickel and cadmium) in the kidney and liver of the Hayle trout were 19 and 34 times higher, respectively, than in the Teign trout population. The gills had 63 times higher concentrations, while there were no differences in metal content in the gut, which suggests that the Hayle fish predominantly take up metals from the water via their gills rather than from food.

This build-up of metals in the Hayle fish highlights the extent to which they are exposed to metals in their environment, and their extraordinary ability to cope with the presence of toxic concentrations of metals both in the water and within their bodies.

Our next step was to investigate how they can do this by searching for the underlying biological mechanisms, specifically by examining gene expression (or activity). Genes provide a blueprint for all processes that occur in the body by encoding and controlling the synthesis of proteins. Genes that are highly expressed (ie



On average, the concentration of metals in the kidney and liver of the Hayle trout were 19 and 34 times higher.

very active) usually indicate high synthesis of the corresponding protein, which results in the regulation of associated physiological effects. We used an advanced technique called high-throughput sequencing, which involves first building the transcriptome (all of the expressed genes) for this species, then measuring and comparing the expression level of individual genes in fish from each river.

Our data showed that the gene encoding a protein called metallothionein, which is responsible for binding, storing and detoxifying a number of metals, was highly expressed in the River Hayle trout compared to the control fish, as were a number of other metal-binding and transporting proteins. This indicates that a natural response system is activated in the Hayle trout which enhances their ability to cope with the metals they take up.

One of the ways that metals usually poison fish is by creating toxic forms of oxygen that cause oxidative damage in cells, and by disrupting the balance of ions in the body. We found evidence that the Hayle fish counter this toxicity through changes in the expression of a number of genes that are important in maintaining the balance of salts and ions in the body, as well as a modest increase in antioxidants which defend against oxidative damage.

Metal contamination in freshwater is a worldwide problem. There are other fish populations living in rivers with similar metal contamination as the Hayle which, generally, appear to show more signs of

metal toxicity. The ability of the Hayle trout to tolerate and flourish in such a contaminated environment therefore seems quite extraordinary.

The story of the brown trout from the River Hayle is fascinating. It demonstrates the resilience of these fish and their ability to defeat the odds and tolerate the challenges imposed on them by human activities. Many aspects of this story remain untold: we do not know how or when this tolerance arose and, most importantly, we do not know what the future holds for these fish if they face new environmental stresses in the future.

But we know that such populations need careful management. If we lose these fish, with their unique physiology, it is possible that brown trout may not return to the Hayle. This story demonstrates how important it is to understand the relationship of fish with their environment so we can effectively manage and protect our aquatic ecosystems.



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Soil doctors

A collaboration between scientists and food suppliers is improving how we manage one of the most crucial ingredients for growing vegetables. Sue Nelson met Karl Ritz, Robert Simmons and Guy Thallon outside Cranfield University's National Soil Resources Institute, to find out about Soil for Life.

Sue Nelson: We take soil for granted; some of us may even have eaten it as a child. But what exactly is it?

Karl Ritz: Soil is one of the most remarkable materials on the planet. It's composed of a wide range of minerals, organic matter and, most importantly of all, space. Soil is porous and it's those pores that hold water, allow plant roots to penetrate and provide a habitat for the myriad of organisms that drive soil function.

Sue Nelson: What makes a good soil?

Karl Ritz: A good soil is one that is fit for purpose, so it depends what you want to do with it. You would need different properties if you want to grow things in it or if you want to make a cricket pitch on it.

Robert Simmons: A good soil for vegetables forms a good tilth – a crumbly structure that allows enough contact between seed and soil for good germination but also means the soil is free draining. Soils have to retain and release nutrients and have good aeration, but after that requirements become specific for different crops, so you need different soils for onions and root crops, for example.

Sue Nelson: What actually happens when a soil has been overused, as can be the case when it's intensively farmed for vegetables for supermarkets?

Robert Simmons: A number of things happen; effectively the soil is getting tired – in Lincolnshire they say 'whacked'. The soil begins to degrade and starts to lose its ability to perform certain functions. So it can become compacted and that impacts on soil

structure and its ability to receive, retain and release water. Soil structure can also decline through lack of organic matter; intensive production systems can affect the microbes in the soil which in turn affects nutrient recycling and soil structure. You also start having problems with capping of the surface, where the soil surface breaks down under rainfall and forms a cap which then stops water getting in.

You can also get a build-up of soil-borne diseases which are specific to particular crops – potato cyst nematodes for example – and that's why crop rotation is so important. You may need to look at some chemical solutions, like nematocides, or bio-fumigants.

Sue Nelson: Karl, several years ago you came up with an idea to help growers monitor their soil. But why – surely farmers keep an eye on this sort of thing themselves?

Karl Ritz: Individual growers and farmers of course monitor their soils regularly but agriculture is changing. Many farmers now grow crops for large supplier companies. Data about individual growers' own fields and produce, isolated from other growers, isn't very useful for understanding what's happening across a whole area being farmed for one supplier. The data needed to be integrated in a way that could provide important business-related information for the supplier which could also be passed back to the growers.

Sue Nelson: And this led to a link with Produce World, one of the largest vegetable suppliers in Europe. Guy, you worked with Produce World on the Soil for Life project for three years – what did you do?



i This Q&A is adapted from the Planet Earth Podcast, 26 November 2013. The full podcast and transcript are on Planet Earth Online <http://planetearth.nerc.ac.uk/multimedia/story.aspx?id=1559>
Soil for Life <http://soil-for-life.co.uk/>

Guy Thallon: The project was about bringing the individual farm-system data Karl was talking about together into one place where it could be analysed. Produce World is a large fresh produce company; they supply alliums – onions and leeks – brassicas – broccoli, cauliflower – green leafy veg, potatoes and root crops into supermarkets. About a third of that is grown on their own farms and the rest comes from partner farms and growers. I worked with in-house and partner farms, mapping the land being used and recording crop management and farm management data, information about their machinery and farm gear, and also on fertilizers and crop nutrition.

Sue Nelson: And yield as well I assume?

Guy Thallon: Absolutely. As suppliers Produce World has in-depth data on the yield and quality of produce coming through. Their goal is not necessarily about getting the most off the land though – it's about maximising the amount which is of saleable quality – marketable yield.

Thankfully I did have a laptop as I was moving around visiting farmers and growers and asking them to contribute data. Soil for Life itself is a database and information system which identifies fields and links data to those fields. We can then use that data to look at different case studies and understand the different soils growers are working with.

Karl Ritz: For the first time we'll have a large, coherent database which will grow every year as more information is added. As the data are connected we can start to explore it in new ways using what's called data mining – new statistical tools that can look

at lots of data at once. One of the names for this is 'big data' – it's becoming common in genetics but here we're applying it to environmental information.

Sue Nelson: Guy, what area does the database cover?

Guy Thallon: Mainly the east of England at the moment – most of Produce World's farms and growers are in south Lincolnshire and East Anglia. We have data on about 800 fields covering about 10,000 hectares.

Sue Nelson: And what will the benefits be for farmers?

Robert Simmons: Some UK growers can lose 40 per cent of their product through defects. Soil for Life can identify which farming practices are most likely to produce marketable crops on a particular type of soil, to reduce wastage – for example fertilizer inputs, tillage practices and irrigation. The beauty of Soil for Life is you can use it to make economic assessments of your production system to identify where you can make savings, not just in terms of things like fertilizer but in terms of energy and carbon.

Sue Nelson: Is it useful for policy as well?

Guy Thallon: Definitely. Food production is really high on the government's agenda. This year's UK Agri-Tech Strategy introduced the idea of sustainable intensification, which basically means increasing food production whilst decreasing the environmental impacts – so minimising the damage you are doing to resources such as soil. The data we've got in Soil for Life and the understanding we can derive from it can have huge benefits for driving forward that sustainable intensification agenda.



Skull of a Galapagos sealion pup on the island of Santa Fe.

Paddy Brock, Imperial College London.



Investigating the role of UV-B light in plant development.

Scott Hayes, University of Bristol.



Working out of a 4x4 mobile laboratory in the South African Kalahari Desert.

Dominic Cram, University of Exeter.



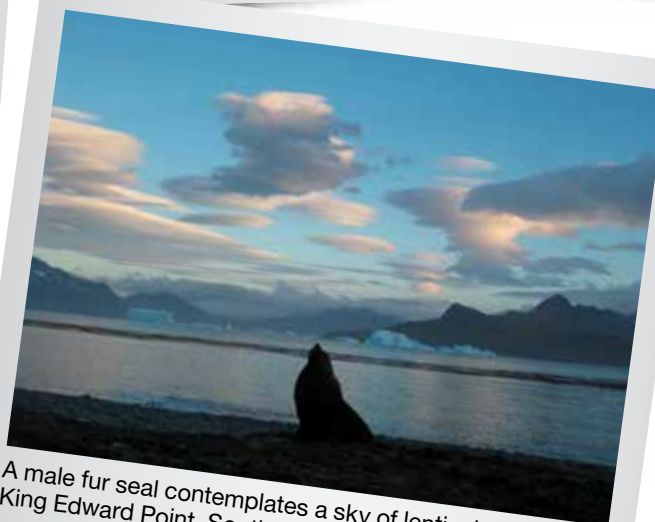
Weighing an elephant in Myanmar.

Hannah Mumby, University of Sheffield.



Standing on the crater rim, looking out on Lake Lanoto'o in Samoa.

Jonathan Hassall, University of Southampton.



A male fur seal contemplates a sky of lenticular clouds at King Edward Point, South Georgia.

Daniel Bannister, University of East Anglia and British Antarctic Survey.

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